PTO 09-2763

CC = WO
20030213
A1
03012156

METHOD FOR MAKING A MECHANICAL COMPONENT, AND RESULTING MECHANICAL COMPONENT

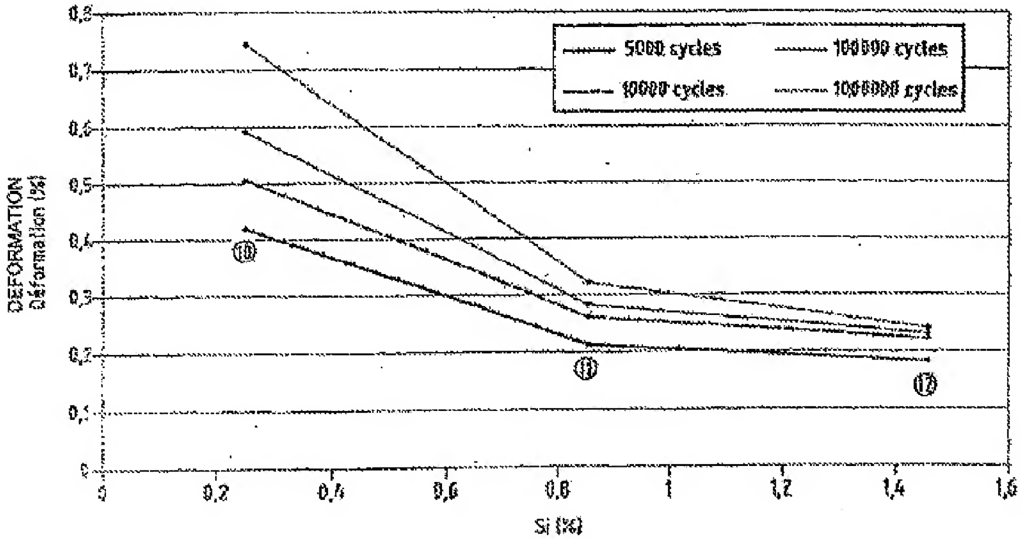
[Procede de fabrication d'une piece mecanique, et piece mecanique ainsi realisee]

André Badard et al.

UNITED STATES PATENT AND TRADEMARK OFFICE
WASHINGTON, D.C. FEBRUARY 2009
TRANSLATED BY: THE MCELROY TRANSLATION COMPANY

PUBLICATION COUNTRY	(19):	WO
DOCUMENT NUMBER	(10):	03012156
DOCUMENT KIND	(12):	A1
PUBLICATION DATE	(43):	20030213
APPLICATION NUMBER	(21):	PCT/FR02/02596
APPLICATION DATE	(22):	20020719
INTERNATIONAL CLASSIFICATION[7]	(51):	C 22 C 38/18
		38/04
		38/02
		C 23 C 8/22
		8/32
PRIORITY COUNTRY	(30):	FR
PRIORITY NUMBER	(30):	0109871
PRIORITY DATE	(30):	20010724
INVENTORS	(72):	André Badard et al.
APPLICANT	(71):	ASCOMETAL [FR/FR]
DESIGNATED CONTRACTING STATES		
(national):	(81):	AE, AG, AL, AM, AT, AU, AZ, BA, BB, BG, BR, BY, BZ, CA, CH, CN, CO, CR, CU, CZ, DE, DK, DM, DZ, EC, EE, ES, FI, GB, GD, GE, GH, GM, HR, HU, ID, IL, IN, IS, IP, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MA, MD, MG, MK, MN, MW, MX, MZ,

		NO, NZ, OM, PH, PL, PT, RO, RU, SD, SE, SG, SI, SK, SL, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VN, YU, ZA, ZM, ZW.
DESIGNATED CONTRACTING STATES (regional):	(84)	ARIPO patent (GH, GM, KE, LS, MW, MZ, SD, SL, SZ, TZ, UG, ZM, ZW), Eurasian patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European patent (AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FL, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE, SK, TR), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, ML, MR, NE, SN, TD, TG).
TITLE	(54):	METHOD FOR MAKING A MECHANICAL COMPONENT, AND RESULTING MECHANICAL COMPONENT
FOREIGN TITLE	[54A]:	Procede de fabrication d'une piece mecanique, et piece mecanique ainsi realisee



(57) Abstract: The invention concerns a method for making a steel mechanical component, characterised in that the steel composition is, in wt. %: $0.12 \leq C \leq 0.30$ %; $0.8 \leq Si \leq 1.5$ %; $1.0 \leq Mn \leq 1.6$ %; $0.4 \leq Cr \leq 1.6$ %; $0 \leq Mo \leq 0.30$ %; $0 \leq Ni \leq 0.6$ %; $0 \leq Al \leq 0.06$ %; $0 \leq Cu \leq 0.30$ %; $0 \leq S \leq 0.10$ %; $0 \leq P \leq 0.03$ %; $0 \leq Nb \leq 0.050$ %; the balance being iron and impurities resulting from the manufacturing process, and it consists in subjecting the component to low-pressure carburizing and low-pressure carbonitriding. The invention also concerns the resulting mechanical component.

The invention relates to the domain of iron and steel metallurgy, and, more precisely, the domain of steel mechanical components such as pinions. /1*

Steels for gearing must have a great resistance to contact fatigue. Most of the time, they are treated by carburizing or by carbonitriding so as to give them adequate surface hardness and mechanical resistance, while keeping an adequate core stiffness in particular due to a carbon content on the order of 0.10 to 0.30% only. In the carburized layer, this carbon content may go up to about 1%.

Document US-A-5,518,685 describes steels for gearing meant to be carburized. They contain mainly, in weight percentages, 0.18 to 0.25% of C, 0.45 to 1% of Si, 0.40 to 0.70% of Mn, 0.30 to 0.70% of Ni, 1.0 to 1.5% of Cr, 0.30 to 0.70% of Mo, up to 0.50% of Cu, 0.015 to 0.030% of Al, 0.03 to 0.30% of V, 0.010 to 0.030% of Nb, up to 15 ppm of O, from 100 to 200 ppm of N. After carburizing, they undergo a

* [Numbers in right margin indicate pagination of the original text.]

quench, temper and stress relieve processing which prevents the formation of ferrite in the core. The Si and Mn contents are kept here at relatively low limits, so as to prevent an intergranular oxidation during the carburizing process.

Document JP-A-4-21757 describes steels for gearing meant to be carburized by plasma or under reduced pressure, then shot blasted.

Their composition in weight percentages is 0.10 to 0.30% of C, 0.25 to 1.50% of Si, 0.2 to 2% of Mn, up to 0.015% of P, up to 0.020% of S, up to 2% of Cr, from 0.2 to 1% of Mo, with Si + Mo between 0.6 and 2%, 0.010 to 0.060% of Al, from 50 to 250 ppm of N and up to 15 ppm of O. These steels have a high resistance to the surface pressure undergone by the pinion, the service life of which is thus extended.

However, pinion users, for example for vehicle gear transmissions, are confronted with the following problem. In the long run, observation can be made of the appearance of sites of play between the various components that constitute the mechanical system into which the pinions are integrated. This play damages the functionality of the components by increasing their cyclic stresses, vibrations, noise annoyances, and by prematurely damaging the components. This play is linked to dimensional /2
modifications of the components that occur either during their thermal and/or thermochemical processing operations, or while they are being used, on account of plastic deformations during operation. To prevent or limit plastic deformations during operation, depending on the component and the stresses, it is sometimes sufficient to act on the properties of the surface layer that corresponds to the zone on which the highest stresses apply, in particular in the gearing domain. But the properties of the substrate (the steel that has undergone carburization) with regard to permanent deformations during the thermal cycle also influence the plastic deformations during operation of the component.

The goal of the invention is to provide mechanical components made of steel, in particular gearing components, having a low degree of deformation during operation, so as to minimize the occurrence of play, by retaining the dimensions and the geometry of the components in question.

To that end, an object of the invention is a method for making a steel mechanical component, characterized by the fact that the composition of the steel is, in weight percentages:

- $0.12 \leq C \leq 0.30\%$
- $0.8 \leq Si \leq 1.5\%$
- $1.0 \leq Mn \leq 1.6\%$
- $0.4 \leq Cr \leq 1.6\%$
- $0 \leq Mo \leq 0.30\%$
- $0. \leq Ni \leq 0.6\%$
- $0 \leq Al \leq 0.06\%$
- $0 \leq Cu \leq 0.30\%$
- $0 \leq S \leq 0.10\%$
- $0 \leq P \leq 0.03\%$
- $0 \leq Nb \leq 0.050\%$

the rest being iron and impurities resulting from the manufacturing process, and by the fact that said component is subjected to a low pressure carburizing or a low pressure carbonitriding.

The steel may also contain at least one element selected up to 0.02% of Te, up to 0.04% of Se, up to 0.07% of Pb, up to 0.05% of Ca, up to 0.08% of Bi.

According to a variant of the invention, the steel contains from 0.008 to 0.05% of Al, from 0.02 to /3
0.05% of Nb, and from 0.007 to 0.025% of N, and carburizing or carbonitriding is carried out between 950 and 1100°C.

Another object of the invention is a mechanical component characterized by the fact that it is made through the preceding method.

This mechanical component may be a gearing component.

The invention consists in adjusting the composition of the steel, in particular its Si and Mn contents, so as to obtain as low as possible a cyclic plastic deformation in operation of the whole component, and in coupling this adjustment of the composition with the carrying out of low-pressure carburizing or carbonitriding.

The plastic deformation in operation depends at the same time on the stresses exerted on the component and on the material being used. It is linked on one hand to the intrinsic mechanical characteristics of the material, in particular to the evolution of the limit of elasticity during the thermal cycle, that is to say the limit of dynamic elasticity, and, on the other hand, it is linked to the structural stability in operation, in particular to the thermal or mechanical stability of the retained austenite that is often present in the materials being used. The austenite can turn into martensite when the component overheats. The inventors determined conditions of chemical composition of a steel for carburized or carbonitrided components that make it possible to minimize the plastic deformation produced during each cycle of stress in operation. They were established by performing a first series of compression tests and by taking measurements of the stability of the austenite on steels whose composition reproduced the stability of the surface layer that was obtained after carburizing steels according to the invention. These results were then obtained by tests performed on samples matching the invention in every respect, which showed that these steels were suitable for making carburized components having, at core, the desired mechanical properties, in particular a low permanent deformation during cyclic stressing.

Low-pressure carburizing or carbonitrizing (on a non-limiting basis of 3 to 20 mbar, or 300 to 2000 Pa), usually followed by a gas quenching which may also be followed by quenching with another

fluid (oil, polymer ...), is a technique that can be used in the automobile gearing domain because of its advantages as regards its performance in operation. As a matter of fact, this technique makes it possible to prevent any oxidizing of the components up to the extreme surface which endows them with a better /4
performance as regards fatigue and operation. During a standard carburizing or carbonitrizing process, a surface oxidizing can be observed, in particular along the grain boundaries, which is very detrimental to the performance in operation. The use of the steel described all the more justifies the use of a low-pressure carburizing or carbonitrizing, as it contains highly oxidizible elements such as Mn and Si and as this technique makes it possible at the same time to limit deformations. Advantageously, this low pressure carburizing or carbonitrizing is performed at high temperature, that is to say between 950 and 1100°C, which makes it possible to divide the processing time by [a factor of] 2 to 3, in comparison to an operation performed at 820 – 930°C as is usually done. In these conditions, it is preferable to adjust the composition of the steel in such a way as to prevent excessive grain growth.

Carburizing and carbonitrizing being two techniques of surface processing with similar objectives and being performed in similar conditions except for the nature of the processing atmosphere, either of them can be equally used in the context of the method according to the invention.

The invention will be better understood when reading the following description, given as a reference in the following figures:

- Figure 1 which shows the degree of permanent deformation undergone during fatigue-compression tests by two steel samples simulating the steels used within the scope of the invention and a reference steel, according to the silicon content of the steel and to the number of deformation cycles;

- Figure 2 which shows this same degree of permanent deformation after 10^6 cycles for different steels that simulate the steels used within the scope of the invention and reference steels, according to their silicon and manganese contents.

- Figure 3 which shows the degree of permanent deformation undergone during fatigue-compression tests by one steel sample used within the scope of the invention and a reference sample of low silicon content, according to the number of deformation cycles.

The steels used within the scope of the invention must have the following composition. All percentages are weight percentages.

Their carbon content must be within 0.12 and 0.3%, which corresponds approximately to the contents usually found in gearing steels. Carburizing or carbonitrizing, as is standard procedure, must /5
bring this content to more than 0.5%, generally between 0.7 and 1% in their surface layer. The carburizing or carbonitrizing process is carried out by low-pressure carburizing or carbonitrizing for the reasons that were stated [above].

The Mn content must be high enough, between 1 and 1.6%, in order to give the steel a hardenability that allows less deformation during thermal and/or thermochemical treatments. By combining it with an Si content between 0.8 and 1.5% it acts, moreover, upon the plastic deformations that can be caused by the cyclic stresses in operation.

The experimental results presented below will make it possible to be more specific about the advantages of this range of Si and Mn contents. It can already be said that too low an Si content results in too high a permanent deformation during cyclic stressing. Too high a content may result in the formation of ferrite islets that are detrimental to the required mechanical properties. It would also make hot or cold forming of the component more difficult. Too low an Mn content is also detrimental to the permanent deformation during cyclic stressing, because the low amount of retained austenite provides insufficient structural stability during deformations. Too high an Mn content results in too high a retained austenite content, which leads to mechanical characteristics of ductility that are too low and permanent deformations that are too high.

The chromium content must be between 0.4 and 1.6% so as to provide the steel with adequate hardenability core mechanical properties that are sufficient in terms of hardness and resistance. A content higher than 1.6% is not necessary any longer from this standpoint; in addition, it makes steel manufacture more difficult.

Optionally present, molybdenum makes it possible to adjust the hardenability of the steel. Above 0.30%, the addition becomes too costly and superfluous for obtaining the hardenability adjustment.

The nickel content (or the content resulting naturally from the steel-making process without any addition of Ni) must be between 0% and 0.6%. The addition of Ni makes it possible to obtain a better shock resistance which may prove to be of importance during the assembly of the mechanical unit into which the component is integrated. Beyond 0.6% no further effect is obtained and the cost of the steel is uselessly increased.

The aluminum content must be between trace amounts resulting from the steel-making process and /6
0.06%. This deoxidizing element is not essential, the deoxidization obtained with silicon and manganese being sufficient. Moreover, if the steel making and the casting are not carried out carefully enough, significant amounts of Al are added, so there is a risk of excessive aluminum oxide inclusions to be present, which constitute initiation sites for fatigue cracks. However, if the steel making and the casting conditions are optimal, it may be interesting to add Al in order to prevent an excessive grain growth during the carburizing or carbonitriding process, which is favorable to a lesser spreading of the cracks. If carburizing or carbonitriding is performed at high temperature, the Al content is preferably 0.008 to 0.05%, in order to prevent an excessive grain growth, in conjunction with preferred Nb and N contents quoted below.

The copper content, resulting from the steel-making process, must not exceed 0.30% so as not to cause the ductility and the stiffness of the core material to deteriorate.

The sulphur content can be between mere trace amounts and 0.10%. This element can be added if a better machinability of the steel is desired.

The phosphorus content must not exceed 0.03%, in order not to cause excessive segregation of the grain boundaries during the tempering process, which would embrittle the steel.

The niobium content can be between mere trace amounts resulting from the steel-making process and 0.050%. An addition of niobium makes it possible to obtain a more homogeneous grain size which facilitates the homogeneity of the plastic deformation in operation and further minimizes this deformation. Beyond 0.050%, the effect of the niobium stops increasing, and an addition at higher contents would uselessly increase the cost of the steel. In the case of a high-temperature carburizing or carbonitriding, the Nb content must preferably be between 0.02 and 0.05%.

In other respects, it is conceivable to add to the steel one or more elements that make it possible to improve its machinability, namely tellurium (up to 0.02%), selenium (up to 0.04%), lead (up to 0.07%), calcium (up to 0.05%), or bismuth (up to 0.08%)

Tests were performed on solid steel samples whose compositions appear in Table 1.

Samples 11 to 16 are a first series of steel samples that cannot be used within the scope of the /7
invention because their carbon content is higher than the required limit. But, as we said previously, their composition simulates the composition of the carburized layer of steels that would be, at core, in accordance with the required composition within the scope of the invention. They make it possible to easily evaluate whether this composition would be adequate for solving the posed problem, which similar experiments conducted on carburized or carbonitrided steel samples within the scope of the invention would not make possible with the same obviousness. Table 1 also gives the composition of various reference samples, which cannot be used within the scope of the invention and do not simulate such steels, but make it possible to appreciate the formability in operation (destabilization of the retained

austenite during cyclic stressing) according to elements Mn and Si, for carburized layers whose analyses are close to those that were obtained on the steel that can be used within the scope of the invention. For all the samples in Table 1, the Ni content was less than 0.25%, the Al content was less than 0.050%, the Cu content was less than 0.2%, and the N content was less than 150 ppm, taking into account that this nitrogen content is not a requirement and could be markedly higher without leaving the scope of the invention. Indeed, a high nitrogen content cannot be ruled out for the types of steel being considered. A relatively high content, from 70 to 250 ppm, is even advised in the case of high-temperature carburizing or carbonitriding.

TABLE 1. Compositions of the samples in the first series of tests (in weight%) /8

Sample No.		C	Mn	Si	Cr	Mo	S	P
Reference samples	1	0.98	0.30	0.20	1.50	–	0.008	0.010
	2	0.985	0.345	1.04	1.49	0.017	0.009	0.007
	3	0.95	0.263	1.51	1.57	0.020	0.006	0.012
	4	0.97	0.297	2.06	1.52	0.019	0.006	0.008
	5	0.95	1.02	0.50	1.61	0.021	0.004	0.011
	6	0.95	1.02	2.50	1.57	0.021	0.007	0.011
	7	0.94	2.11	0.45	1.60	0.020	0.008	0.011
	8	0.97	2.05	1.51	1.54	0.019	0.008	0.011
	9	0.96	2.07	2.51	1.61	0.021	0.007	0.011
	10	0.77	1.26	0.25	1.06	0.107	0.029	0.018

Samples simulating the steels used in the invention	11	0.78	1.27	0.85	1.06	0.108	0.031	0.019
	12	0.77	1.25	1.45	1.05	0.106	0.031	0.013
	13	0.97	1.10	1.08	1.52	0.023	0.010	0.008
	14	0.83	1.02	0.98	1.39	0.003	0.009	0.008
	15	0.88	1.08	0.88	1.49	0.003	0.010	0.007
	16	0.86	1.06	1.07	1.53	0.002	0.008	0.007

A first experiment consisted in evaluating, for these various samples, the stability of the remaining austenite. On one hand, we measured the temperature at which 50% of the volume of remaining austenite was destabilized into martensite. On the other hand, we measured the percentage of remaining austenite destabilized at 350°C, which is a temperature that is anyway higher than the one reached by the components of the invention in their considered privileged uses.

TABLE 2. Stability measurements of the remaining austenite /9

Sample No		Destabilization temperature (°C)	Percentage of remaining austenite destabilized at 350°C
Reference samples	1	200	>95
	2	325	30
	3	350	35
	4	325	25
	5	200	>90
	6	400	<20
	7	275	>60
	8	400	<15
	9	425	<15
	10	220	100
Samples simulating steels usable in the invention	11	350	50
	12	400	15
	13	375	<20
	14	440	25
	15	425	35
	16	375	<45

One will notice that, generally, the samples that present the best remaining austenite stability are those that have the highest Si content, the Mn content also having a second rank influence. Reference

samples 6, 8 and 9, which have at least one of the Mn and Si contents that are higher than what the invention requires, offer very good structural stability characteristics, but with the drawbacks indicated above. Samples 12, 13 and 14 simulating the steels that can be used in the invention have a very good remaining austenite stability. The characteristics of samples 11 and 16 are not as good. But sample 11, because of its relatively low silicon content, compared to the preceding ones, has a low remaining austenite amount from the start. This relative lack of structural stability therefore does not compromise obtaining the properties sought for the components of the invention. As far as sample 16 is concerned, it is mainly its relatively high chromium content that makes its initial amount of remaining austenite a low one, and that the same comments that applied to sample 11 can also be applied to it. /10

In Figure 1, the permanent deformation of a steel sample in the form of a cylindrical pin with a 7 mm diameter and 12 mm height was represented during a fatigue-compression test according to the number of cycles, for a stress of 2000 MPa, at room temperature, and for different Si contents. This test related to samples 10, 11 and 12 of Table 1, for which the Mn content was around 1.25%, and the Si content was respectively 0.25%, 0. 85% and 1.45%.

It can be seen that for reference sample 10 with a 0.25% Si content, the permanent deformation goes from 0.42% after 5000 cycles to 0.75% after 10^6 cycles. On the other hand, this permanent deformation is much lower for the steels that simulate the ones that can be used within the scope of the invention. For sample 11 with a Si content of 0.85%, the permanent deformation goes from 0.21% after 5000 cycles to 0.32% after 10^6 cycles. For sample 12 with a Si content of 1.45%, the permanent deformation goes from 0.18% after 5000 cycles to 0.24% after 10^6 cycles.

Figure 2 illustrates the permanent deformation undergone by various samples, in the form mentioned before, after 10^6 cycles, according to the couple (Si%, Mn%). In the figure the numbers of the related samples were transferred, and they can be divided in three curves that correspond to Mn contents on the

order of 0.3%, 1% and 2%. The best results are obtained with reference samples 2, 3, 5, 6 and with samples 13, 14, 15 and 16 that simulate the steels that can be used within the scope of the invention, namely permanent deformations lower than 0.8%. However, we have seen that samples 2, 3 and 5 had moreover an insufficient stability of the remaining austenite, whereas sample 6 has an excessive Si content which may result in the formation of ferrite islets and make the forming of the component difficult. Samples 13, 14 15, 16 with around 1% of Mn and 1% of Si give good results on all levels.

Figure 3 illustrates the permanent deformation undergone by two samples from a second series of tests, in the form mentioned before, for a stress of 1000 MPa, at room temperature. These samples had the compositions transferred in Table 3.

TABLE 3. Compositions of the samples in the second series of tests (in weight%) /11

	C	Mn	Si	Cr	Mo	S	P
Reference samples	0.23	1.27	0.22	1.09	0.10	0.030	0.016
Samples that can be used in the invention	0.23	1.32	0.95	1.11	0.10	0.032	0.016

The sample with 0.95% of silicon was therefore in accordance with the steels that can be used in the invention on all levels. The reference sample differed from it only by its lower silicon content. In Figure 3 we can see that the raising of the silicon content to a value that is in accordance with the ones required by the invention provides the low permanent deformation desired for the core of the carburized components of the invention.

These tests show that the best compromise among the different required properties, for carburized mechanical components that have to be contact fatigue resistant and show very little deformation during thermochemical treatments and during their operation, is obtained for steels that simulate the carburized layers of the steels used in the method according to the invention. This justifies the range of compositions imposed upon these steels.

Claims /12

1. A method for making a steel mechanical component, characterized by the fact that a steel component is made with a composition in weight percentages of:

- $0.12 \leq C \leq 0.30\%$
- $0.8 \leq Si \leq 1.5\%$
- $1.0 \leq Mn \leq 1.6\%$
- $0.4 \leq Cr \leq 1.6\%$
- $0 \leq Mo \leq 0.30\%$
- $0. \leq Ni \leq 0.6\%$
- $0 \leq Al \leq 0.06\%$
- $0 \leq Cu \leq 0.30\%$
- $0 \leq S \leq 0.10\%$
- $0 \leq P \leq 0.03\%$
- $0 \leq Nb \leq 0.050\%$

the rest being iron and impurities resulting from the manufacturing process, and from the fact that said component is subjected to a low-pressure carburizing or a low-pressure carbonitriding.

2. A method according to Claim 1, characterized by the fact that the steel contains at least one element selected up to 0.02% of Te, up to 0.04% of Se, up to 0.07% of Pb, up to 0.05% of Ca, up to 0.08% of Bi.

3. A method according to Claim 1 or 2, characterized by the fact that the steel contains from 0.008 to 0.05% of Al, from 0.02 to 0.05% of Nb, and from 0.007 to 0.025% of N, and by the fact that carburizing or carbonitriding is carried out between 950 and 1100°C.

4. A mechanical component, characterized by the fact that it was made through the method according to one of Claims 1 to 3.

5. A mechanical component according to Claim 4, characterized by the fact that it is a gearing component.

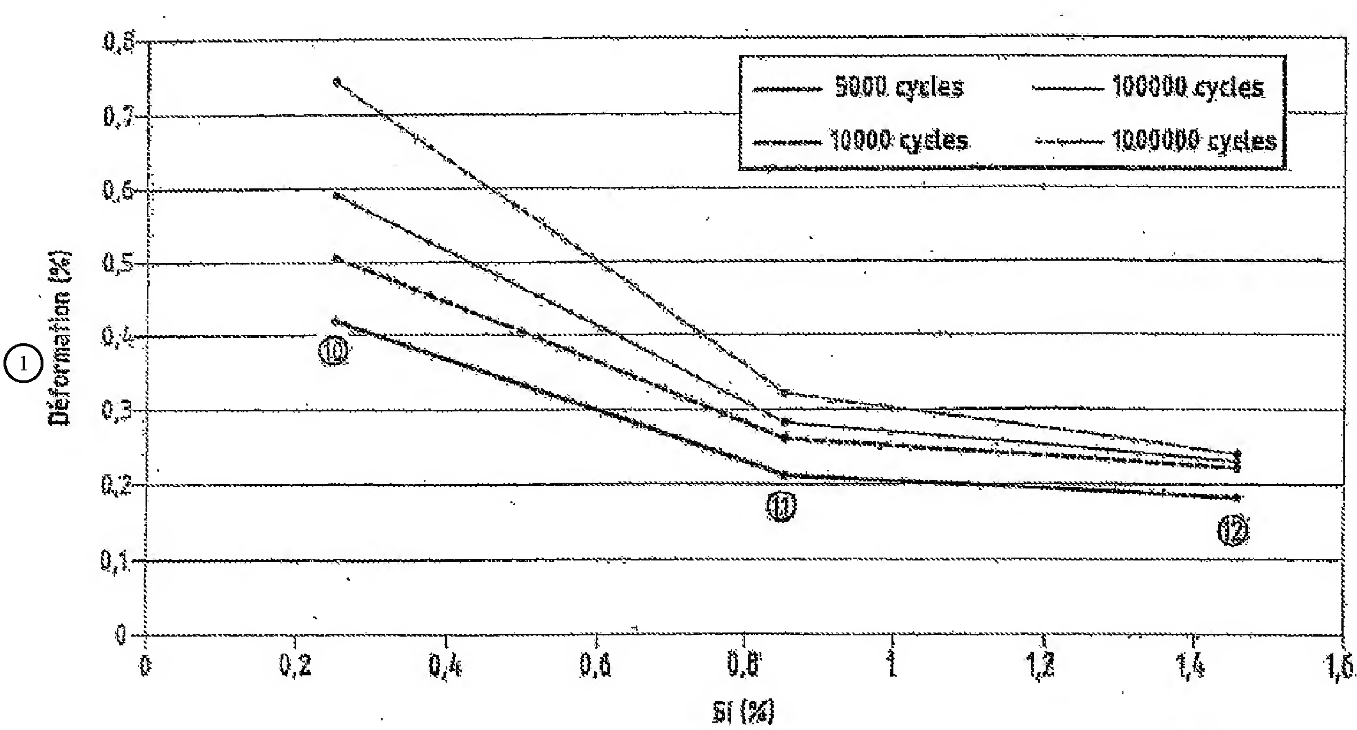


FIG.1

Key: 1 Deformation (%)

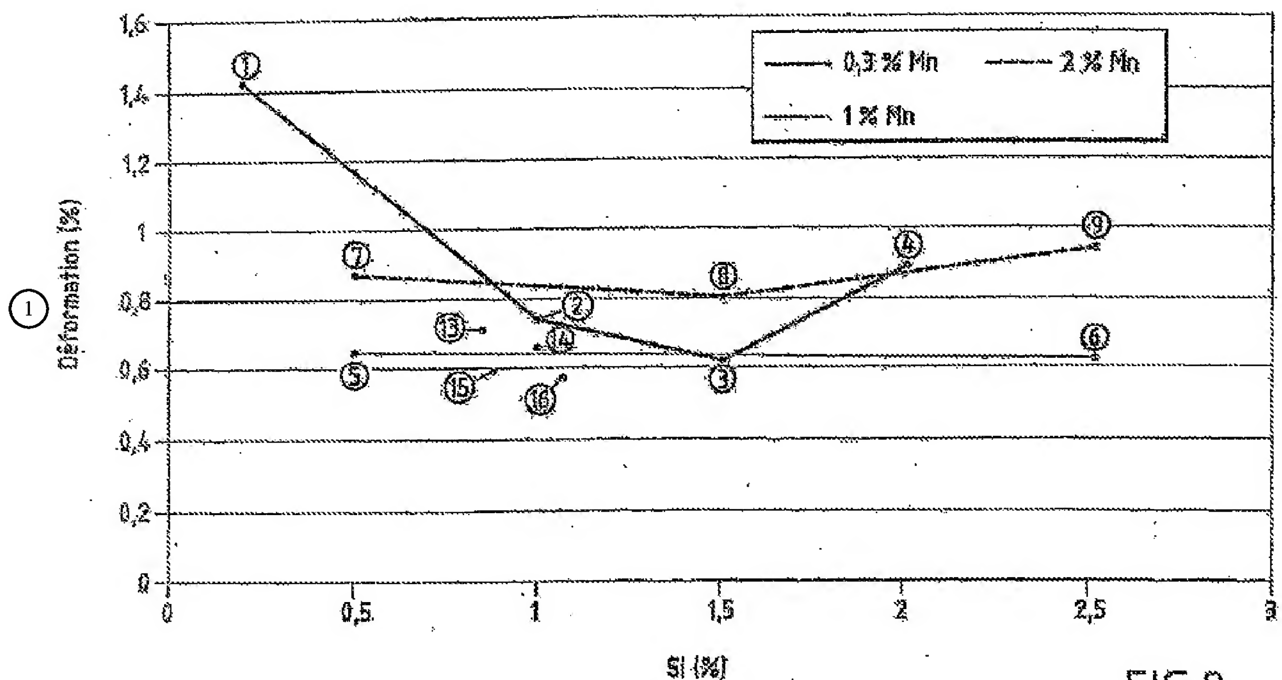


FIG.2

Key: 1 Deformation (%)

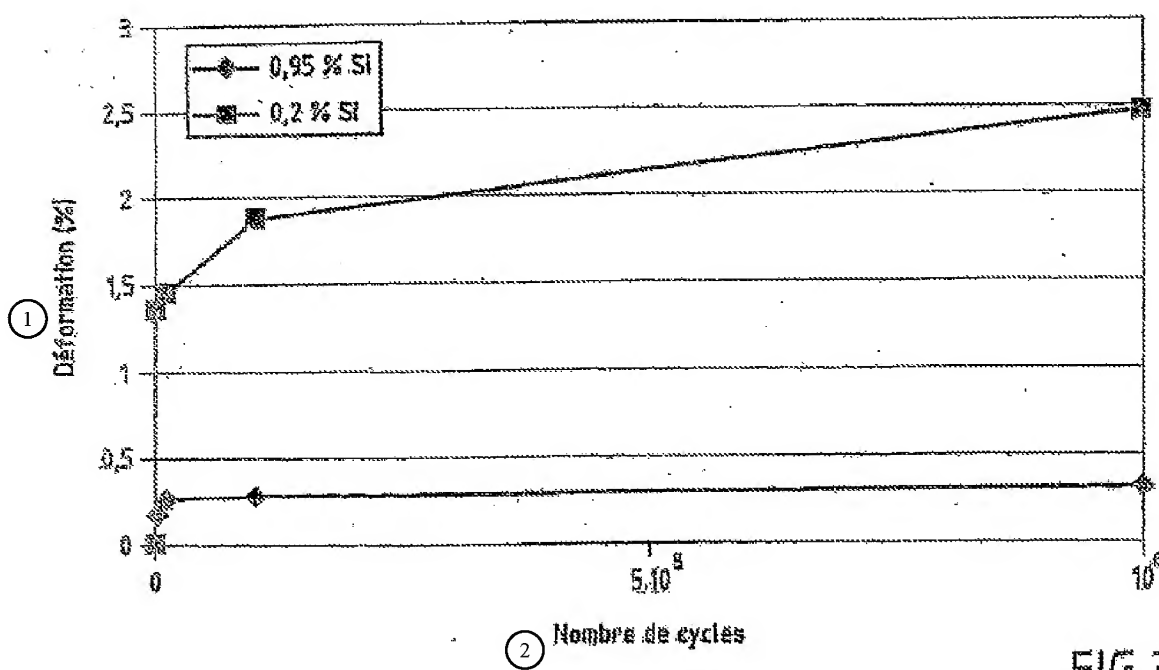


FIG.3

Key: 1 Deformation (%)

2 Number of cycles

INTERNATIONAL SEARCH REPORT

Int ... onal Application No
PCT/FR 02/02596

A. CLASSIFICATION OF SUBJECT MATTER
IPC 7 C22C38/18 C22C38/04 C22C38/02 C23C8/22 C23C8/32

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED
Minimum documentation searched (classification system followed by classification symbols)
IPC 7 C22C C23C

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)
PAJ, EPO-Internal, WPI Data, CHEM ABS Data, COMPENDEX

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	PATENT ABSTRACTS OF JAPAN vol. 2000, no. 13, 5 February 2001 (2001-02-05) -& JP 2000 273574 A (MITSUBISHI SEIKO MURORAN TOKUSHUKO KK), 3 October 2000 (2000-10-03) abstract	1-5
X	EP 1 069 198 A (SUMITOMO METAL IND) 17 January 2001 (2001-01-17) claims 1-6 examples 1-5	1-5

-/--

[X] Further documents are listed in the continuation of box C.

[X] Patent family members are listed in annex.

* Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance
"E" earlier document but published on or after the international filing date
"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
"O" document referring to an oral disclosure, use, exhibition or other means
"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.
"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
29 October 2002	06/11/2002

Name and mailing address of the ISA	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Tx. 31 651 epo nl, Fax: (+31-70) 340-3016	Vlassi, E

Form PCT/ISA/210 (second sheet) (July 1992)

INTERNATIONAL SEARCH REPORT

International Application No
PCT/FR 02/02596

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	PATENT ABSTRACTS OF JAPAN vol. 1997, no. 07, 31 July 1997 (1997-07-31) -& JP 09 059756 A (KOBE STEEL LTD), 4 March 1997 (1997-03-04) abstract	1-5
X	PATENT ABSTRACTS OF JAPAN vol. 1998, no. 03, 27 February 1998 (1998-02-27) -& JP 09 287644 A (TOA STEEL CO LTD), 4 November 1997 (1997-11-04)	1,3-5
A	abstract	2
X	PATENT ABSTRACTS OF JAPAN vol. 1997, no. 08, 29 August 1997 (1997-08-29) -& JP 09 111403 A (TOA STEEL CO LTD), 28 April 1997 (1997-04-28)	1,3-5
A	abstract	2
X	EP 0 769 566 A (TOA STEEL CO LTD) 23 April 1997 (1997-04-23)	1,3-5
A	claims 1-32 examples 1-3	2
X	PATENT ABSTRACTS OF JAPAN vol. 014, no. 470 (C-0769), 15 October 1990 (1990-10-15) -& JP 02 194149 A (NIPPON STEEL CORP), 31 July 1990 (1990-07-31)	1,3-5
A	abstract	2
X	PATENT ABSTRACTS OF JAPAN vol. 1996, no. 08, 30 August 1996 (1996-08-30) -& JP 08 109435 A (TOA STEEL CO LTD), 30 April 1996 (1996-04-30)	1,3-5
A	abstract	2
X	PATENT ABSTRACTS OF JAPAN vol. 016, no. 180 (C-0935), 30 April 1992 (1992-04-30) -& JP 04 021757 A (NISSAN MOTOR CO LTD;OTHERS: 01), 24 January 1992 (1992-01-24) cited in the application	1,3-5
A	abstract	2
A	EP 0 465 333 A (AUBERT & DUVAL ACIERIES) 8 January 1992 (1992-01-08) page 3, line 1 -page 4, line 57	1-5

-/--

Form PCT/ISA/210 (continuation of second sheet) (July 1992)

INTERNATIONAL SEARCH REPORT	International Application No PCT/FR 02/02596

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication,where appropriate, of the relevant passages	Relevant to claim No.
A	FR 2 784 692 A (AUBERT & DUVAL SA) 21 April 2000 (2000-04-21) claims 1-14	1-5

Form PCT/ISA/210 (continuation of second sheet) (July 1992)